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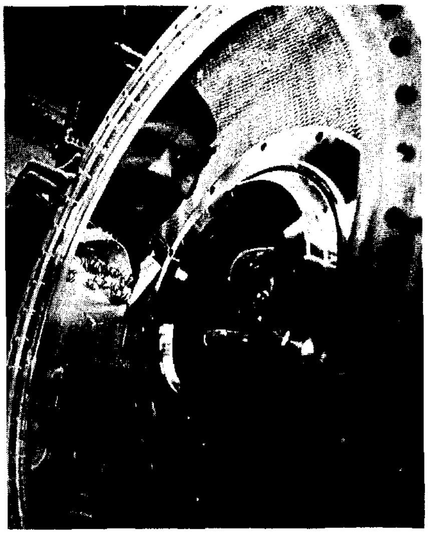

ON THE COVER:

Bob Hamm, MP-12, displays one of the working parts for the PIGMI project — a small accelerator that could allow regional hospitals to treat cancer patients with pions as is being done in Los Alamos with a half-mile-long machine. The ion source pictured, and other photos by LeRoy N. Sanchez, are part of this special issue.

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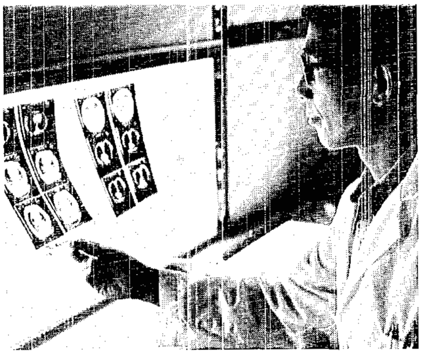
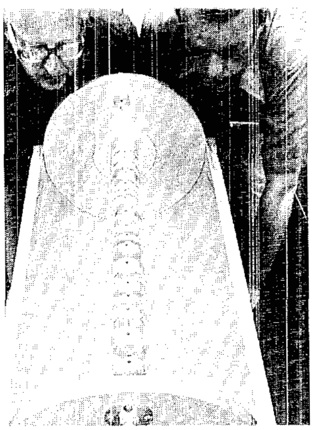
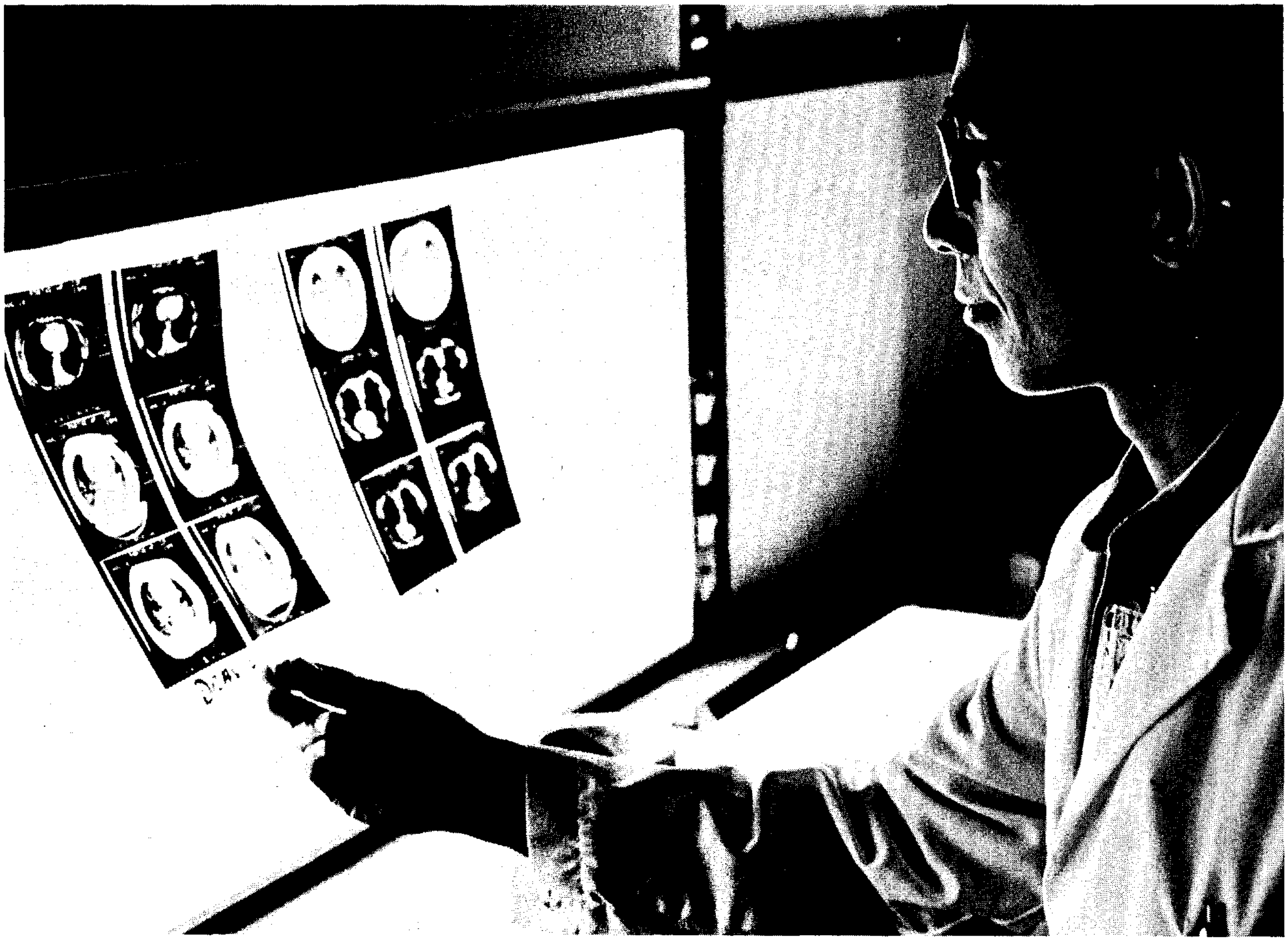
The amazing pion





Stories by Jeff Pederson
Photos by LeRoy N. Sanchez

Japanese visitors are part of new cooperative program



Jeff Pederson photo

Hirohiko Tsujii examines photographs of a patient that will help the biomedical staff determine the best pion treatment scheme for the individual.

On the desk of MP-Division leader Louis Rosen lay a copy of the Yomiuri Shimbun, Japan's largest daily newspaper. Rosen is not a subscriber to that periodical, nor can he read Japanese script. But he knew the issue contained one in a series of articles that dealt with life in the United States, pion treatment of cancer patients, and progress with the smaller-scale "PIGMI" accelerator.

The article was written by Hikaru Inoue, a member of the first team of Japanese selected to stay in Los Alamos for a year to study biomedical applications of pions, which are produced at the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF). In what may seem to occidentals a curious arrangement, the Yomiuri Shimbun was underwriting the costs of the visits of two Japanese researchers -- on the condition they each write three or four articles a year for the paper's seven million subscribers.

The first wave of Japanese left this year for their home country, exporting some of the technology from Los Alamos to Japan for peaceful atomic research applications. They have been replaced by the second group of visitors; each has been recommended by the prestigious Pion Therapy Research Group in Japan.

Began with 1976 visit

"It was a little over two years ago that Seitaro Nakamura, the first student of Nobel Prize winner Hideki Yukawa, visited us," recalled Rosen. "Yukawa had predicted the existence of the pion, which is now used in cancer research, in 1934. Nakamura is a professor of physics at Tokyo University and Nijon University, and he related how the elderly Yukawa wanted to know if his discovery was being used here for beneficial purposes."

No meson factories in Japan

Yukawa had heard of the pion treatment being performed at the biomedical facilities at LASL in conjunction with the University of New Mexico Cancer Research and Treatment Center, and LASL sent some additional information to Japan.

Nakamura also asked Rosen if he would care to visit Japan, and a letter of invitation appeared about a year later. The MP-Division leader toured and spoke to groups of researchers there, and appeared on national television where a panel of experts asked him what Japan could do regarding pion treatment.

"I told them the best thing would be to come over here and learn," Rosen recalled. "They took me up on it. These visitors have been of help to us and are very competent persons. Now an editor of the monthly Gendai has requested to come; their survey shows the Japanese feel cancer is the most important problem in their country today."

* * *

Many Japanese will await the outcome of the pion therapy before actually building a machine, said Tsujii, who occasionally works until 6 a.m. when patients are being treated under the beam. In the present cycle, 13 patients are being treated in 20-23 fields, he said.

"When I first came I asked Kligerman (the project director) what he wanted me to do," said Tsujii. "He said to do everything I can." That means seeing patients, making weekend calls, examining, performing scans of the body. Then simulations show if the pion beam will be hitting the proper tumor location.

Toraji Irefune, a physicist, writes articles for the Yomiuri Shimbun as does Tsujii. He works for the Japanese Foundation for Cancer Research, just north of Tokyo, which launched the first cancer research campaign in that country in 1908, and which operates with a staff of 52.

'I told them the best thing would be to come over here and learn'

Three here now

Three Japanese researchers will be in Los Alamos until late spring, 1979. They constitute a second wave of visitors at MP-Division and AT-Division.

Hirohiko Tsujii, a physician, works with conventional radiotherapy at the Hokaido University in Sapporo, northern Japan. "There is a big concern with pion treatment in Japan," he said. The government has given two grants to study pion treatment and neutron treatment, said Tsujii, who previously spent two years in New York completing his residency. "Cancer is the second leading cause of death in my country, following vascular problems," he said.

"At first, we have to know the system," said Irefune, "how pions are made, and the many steps that are needed before the patient is treated. I think many people have an interest in PIGMI, as well. Since there is only the medical application, for the most part, there would be few political problems."

Irefune works in MP-3 under the direction of Jim Bradbury. Critical dosimetry involves a direct measurement of the dose received by each patient for each field of treatment. This work is performed when pions are not being delivered -- normally between midnight and dawn. He also works with computerized treatment planning, designed to give the optimal treatment for each patient.

Pions . . . green chile

"We will need a pion machine eventually," said Irefune, "because there is no central repository of pion research or knowledge in Japan. The government probably would support the building of a machine."

Like other Japanese visitors, Irefune found he had to go to Albuquerque for some time to procure the proper rice for the diet to which he was accustomed. But now, he said, "I've gotten to like the New Mexican green chile."

From Hokaido University, Foundation for Cancer Research, Laboratory for High Energy Physics

Shigemi Inagaki, a physicist, works for the National Laboratory for High Energy Physics north of Tokyo. Part of a sprawling complex devoted to educational research in a variety of scientific fields, the laboratory is home to a cyclotron that has a 20 million electron volt energy and a 500 million electron volt booster, said Inagaki.

The first graduate of a new department of the University of Tokyo, Inagaki received his degree in 1966 and studies the "boundary regions of science" and how physics, chemistry, biology, and mathematics interact. Although he arrived in August, his wife can't come to Los Alamos until next July because she is unable to leave her teaching position until then.

"The pion therapy and PIGMI are both exciting," said Inagaki, who works with Don Swenson, AT-1. "But the exchange of knowledge between different scientific fields in Japan may not happen for awhile. The medical doctors, for instance, consider themselves different, and so do the professors at universities. I hope this changes, but it may not until everyone — from physicists to technicians — are given the same weight. PIGMI is complicated, and needs a team of experts."

* * *

First group returned

The first group of Japanese visitors has returned, but they discussed before their departure aspects of their work here and the therapy research group that Nakamura organized in Japan at the request of the Nobel Prize-winning Yukawa.

Hikaru Inoue, a physicist from Hiroshima University, had never worked with pions before. He came to Los Alamos with his wife Fumie and two children; his 11-year-old son enjoyed the Mountain School experience. Inoue learned his English during his stay here.

"We have accelerators in Japan but we have no 'meson factories,' such as LAMPF," said Inoue. "For medical purposes the success of the PIGMI — Pion Generator for Medical Irradiations — is important."

Yoshiaki Tanaka, a physician, works in the department of radiology at the University of Nagoya. Like Inoue, he was sponsored by the Yomiuri Shimbun newspaper. In his first visit to the United States, he worked with the researchers and patients at the biomedical facilities of LAMPF.

"We had seen some coverage of the pion treatment in newspapers before we came," said Tanaka, "Now we find that even one full year is too, too short." There are too few scientific journals in Japan, he said, plus a great public interest in cancer treatment — hence the publishing of results in the newspaper.

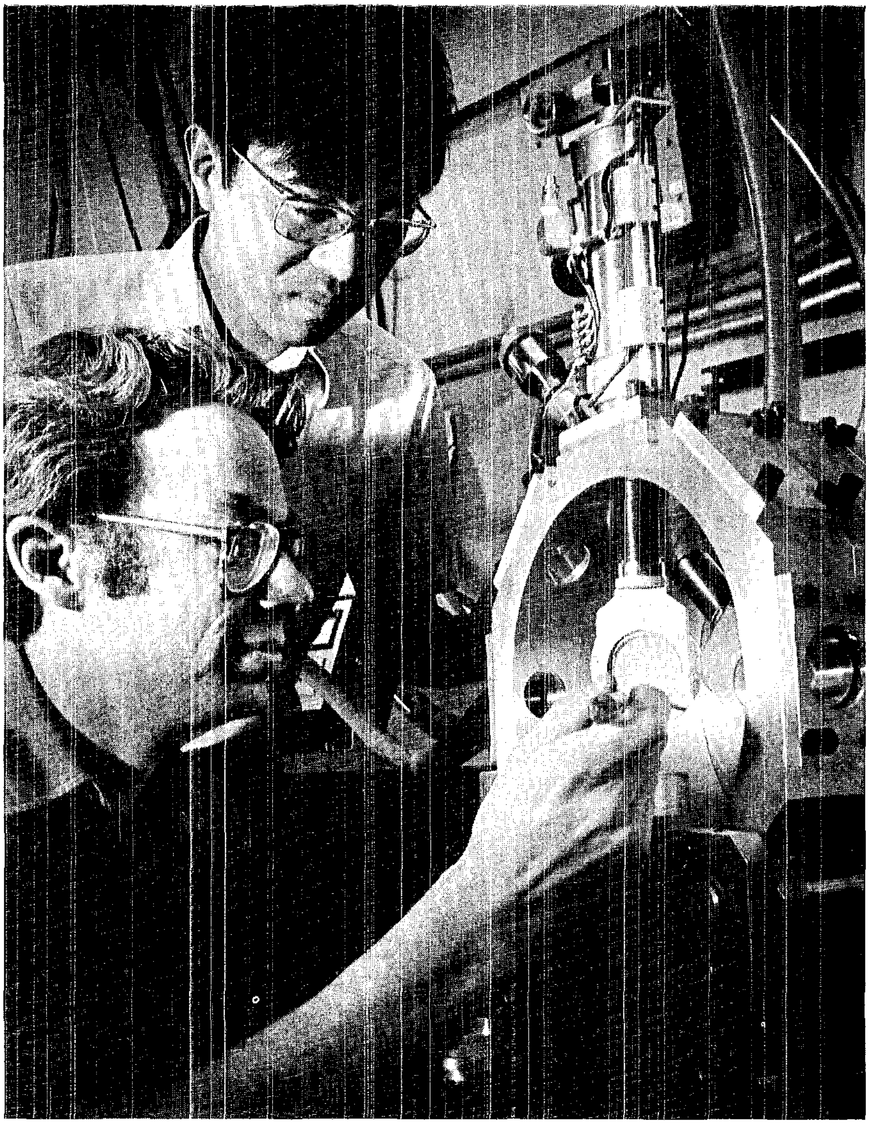
Pion therapy holds the promise of being effective, said Tanaka, because normal tissues are not damaged as with other treatments. "I hope in Japan we can have a pion machine constructed," he said, "perhaps a smaller one, next to a hospital."

Good patient reactions

Tanaka assisted with patient treatment, exams, skin reaction diagnosis, and so forth. "It is my impression," he concluded, "that

Jeff Pederson photo

Toraji Irefune works with critical dosimetry and computerized treatment planning at Los Alamos — sometimes between midnight and dawn.



Shigemi Inagaki works with Jim Stovall, AT-1, on beam diagnostic studies that are important to the success of the PIGMI accelerator project.

'I guess we all hope we can have a machine for cancer treatment in Japan'

pion patients almost always have a good reaction to this therapy. It is different from cobalt and x rays; there is less vomiting and diarrhea. If pion treatment shows better results, we may go ahead with this in Japan."

Norio Saito, a physicist, works with the large Hitachi Company and is an electron beam expert. He left Los Alamos around August 1. "We'll bring back information about pions, energy, and nuclear fusion," he said. "And we will need a proton or electron accelerator for pion treatment. There is no such machine in Japan today."

In Japan, he said, many scientists are hoping for a PIGMI construction because it could have applications beyond pion treatment. Saito, who worked with Don Swenson on the small accelerator project, said the push for an electron accelerator in Japan may diminish if PIGMI succeeds. He was also surprised at the widespread application of computer technology at Los Alamos, and noted that many people have their own terminals.

Michikatsu Takai is a physicist who works for the Hamamatsu School of Medicine. At Los Alamos, he participated in work with microdosimetry and radiation, and also worked in MP-3, the group dedicated to practical applications.

"I had some idea of this," said Takai, "but until we used pions for therapy, it was not necessary to do microdosimetry — measuring the dose absorbed by the patient. So in Japan, few people have done this work. I guess we all hope we can have a charged-particle machine for cancer treatment in Japan."

Atsuo Akanuma, physician from the University of Tokyo, is a radiotherapist who also belongs to an American medical board. "It's too early to tell," he said, "but there certainly are some prospects for this therapy. It will depend on effects and economics, but it is one step higher than other therapies."

There is an anti-nuclear movement in Japan, Akanuma acknowledged, but reactors are not used for medicinal purposes to the extent that a LAMPF accelerator is. A national committee report to the Japanese government last fall stated that such an accelerator was needed.

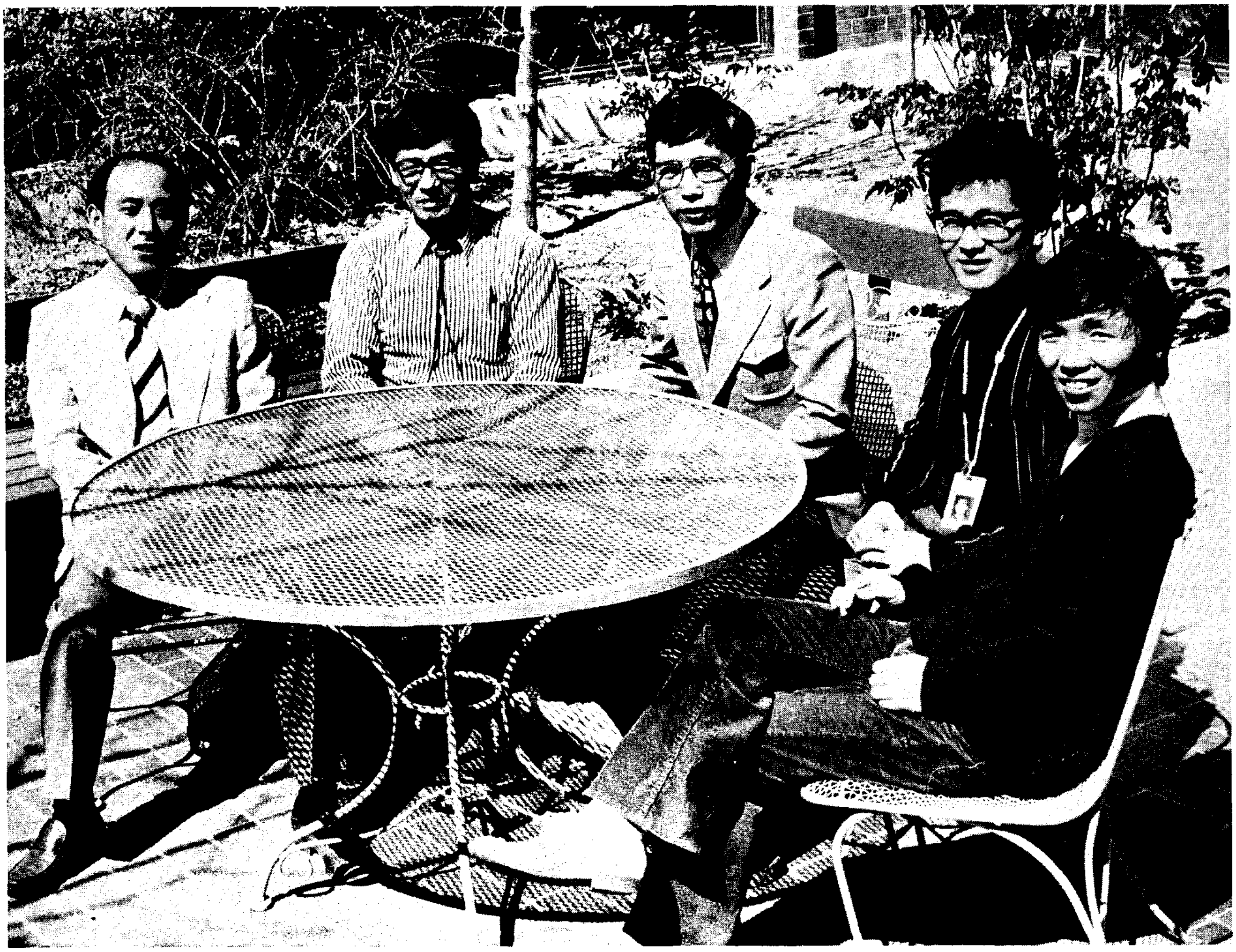
"They're going to build something, but I don't know when," said Akanuma. An accelerator outside Tokyo operates at 58 million electron volts and hopes to reach 90. LAMPF, by contrast, hits 800 million electron volts.

Continuing exchange

The National Institute for Radiological Science seems more interested in protons and heavy ions for therapy, but not pions, said Akanuma. "We will send people from

Japan as long as we can find them," he continued. "If we can buy a PIGMI in two or three years, we will need trained people. The committee would like to send more. Not just to Los Alamos, but to other places too. I certainly have enjoyed the environment in Los Alamos and appreciate the many courtesies extended to us."

Some visitors are supported by the Yomiuri Shimbun and write articles



Jeff Pederson photo

Now back in Japan is the first group of visiting researchers: from left are Yoshiaki Tanaka of the University of Nagoya; Hikaru Inoue from Hiroshima University; Atsuo Akanuma from the University of Tokyo; Nario Saito of the Hitachi Co.; and Michikatsu Takai of the Hamamatsu School of Medicine.

A Nobel Prize for predicting the pion's existence 40 years ago

(Editor's note: The Atom corresponded with Seitaro Nakamura, chairman of the department of physics at Japan's Tokai University, regarding the interest in pion therapy, and asking for comments of Hideki Yukawa, who won a Nobel Prize some 40 years ago for predicting the existence of the pion particle. Reprints of Nakamura's letter and Yukawa's article follow. The translation of Yukawa's article is being printed by the *Atom* exactly as it was received.

* * *

Dear Mr. Pederson:

In response to your letter, I am sending you a copy of a translation of Prof. Yukawa's article, which was printed in the Japanese periodical Sozosei no Sekai (Creative World).

As you suspect, Prof. Yukawa is now in bed and very weak in heart. He expresses his hearty thanks to your very kind consideration.

By the warmest friendship and generosity of Louis Rosen and Morton Kligerman, our young people could have an opportunity of taking part in the remarkable works of meson therapy program in LAMPF.

Four of them who have lately returned talked to us the excitement and hopes of your future accomplishments, which caused a sensation among medical worlds in Japan.

— **Seitaro Nakamura**
Tokai University

"It was great shock when I read a news on the Yomiuri (newspaper) that pion therapy of cancer is now tried and the result of the experiment is satisfactory. The wonderful experiment is undertaken in Los Alamos Scientific Laboratory, and the leaders of the experiment are Louis Rosen and Morton Kligerman. At that time, I was hospitalized and was awaken of my disease, that is a cancer.

"Of course, I did not expect that the pion therapy could be directly used for curing my disease. Even if we start now in Japan following and learning the activity of Los Alamos people, we have to wait many years of construction until the completion of the machine.

"Apart from the treatment of my own disease, this news brought me a great pleasure to see that pion which I imagined forty years ago by

'Great pleasure to see that the pion is useful for rescuing people from the affliction of cancer'

pure reason of theoretical physics is turned out to be useful for rescuing people from the affliction of cancer. Also it encouraged me considerably in my later days of a medical treatment care.

"I know the critical discussion whether the science is primarily good or evil. Such skeptic discussions have been made from a long time ago. It is hard to give a definite answer to this question, since the fruits of science can be used either for the purpose of good or for that of evil. In fact, no one can doubt the destructive use of nuclear physics in the atomic bomb and the hydrogen bomb. This may be considered as a typical example of a misuse of the progress of fundamental physics, which might lead us to a fatal collapse of modern civilization.

"Before such a critical situation, we who are working on the atomic, nuclear, and elementary particle physics regret ourselves deeply. Our long cherished desire is that the results of scientific research should be used for anything good, for the happiness of mankind, and not for destructive purposes.

"It is clear that pion has nothing to do with nuclear weapons. At first, the application of pion was never thought of. I took it to be happy, however, because the possibility of being misused is automatically ruled out. If the possibility of application of pion could ever be realized for the destruction, the damage would be worse.

"In fact, the elementary particle reaction belongs to a higher category than the nuclear reaction, and therefore the effects of the application may be more fearful. So I welcomed the incompetence of meson for the purpose of applications. I can continue my research activity without anxiety of being misused.

"Now the state of things has radically changed. The possibility of peaceful use of pion has been explored by the Los Alamos people. In this situation, I expect its full success for the purpose of medical treatment of cancer. Of course, I hope eagerly that the research works should be undertaken in Japan also, as fast as possible for the completion of pion therapy of cancer.

"However, there are a number of difficult problems. We have not yet constructed a suitable accelerator which enables us to generate pion beams with the ample intensity and with a suitable energy. Also, in order to accomplish a project of building up a pion generator and to proceed with the required research work, we have to settle down to work.

"Several workers in the different fields should come to join the collective works systematically, in physics, medicine, biomedicine, and also technical engineering. This is a sort of inter-disciplinary work, and it is especially difficult in Japan. Our people in the research fields have no such experience.

"So I requested to come and talk together with each other in the Research Institute of Theoretical Physics in the University of Kyoto, where I was a director, and about 20 specialists attended a meeting in December, 1975. They organized a committee of meson medicine and have been preparing for the construction of a national project of a meson factory in Japan."

— Hideki Yukawa

'Several workers in the different fields should come to join the collective work systematically'

Pion treatment in its infancy, with guarded optimism for future

Although treatment of cancer patients with pions has shown some successful results at LASL — regression has been noted in a large percentage of cases — researchers say it is way too early to announce a medical breakthrough.

"Pion therapy is just in its infancy. We are just at the point where we feel we can continue, not to where we can prove our hypotheses," said Morton Kligerman, M.D., director of the University of New Mexico Cancer Research and Treatment Center, and assistant director for radiation therapy at the Laboratory.

Pions not alone

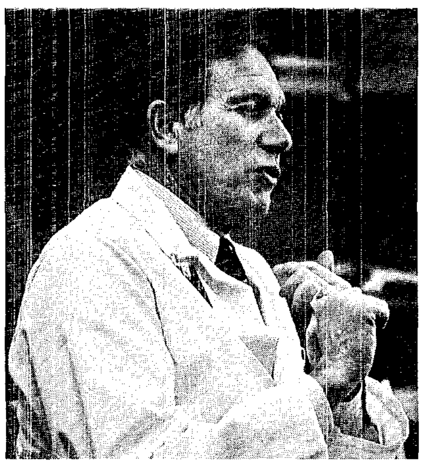
Cancer treatment using various types of particles is being conducted at facilities other than Los Alamos and includes the use of neutrons and heavy ions. Only at the Clinton P. Anderson Los Alamos Meson Physics Facility, however, is pion therapy underway, although pion treatment is planned to begin in Canada and Switzerland within the next one to two years.

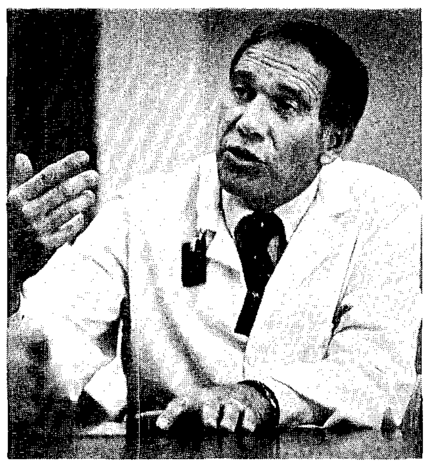
Beams of protons travel down the half-mile pathway at LAMPF, striking several targets — the last of which produces pions (pi mesons) that are directed by large magnets to the treatment area. Pions can be controlled to cause destruction of cancer cells in tumors, largely sparing normal surrounding tissues from intense damage.

"It will take years to say whether pion therapy is superior to other treatments," said Malcolm Bagshaw, M.D., visiting radiation oncologist from Stanford University. "We are looking for local control where cancer has started. We probably can't do too much about a cancer that has spread through the body."

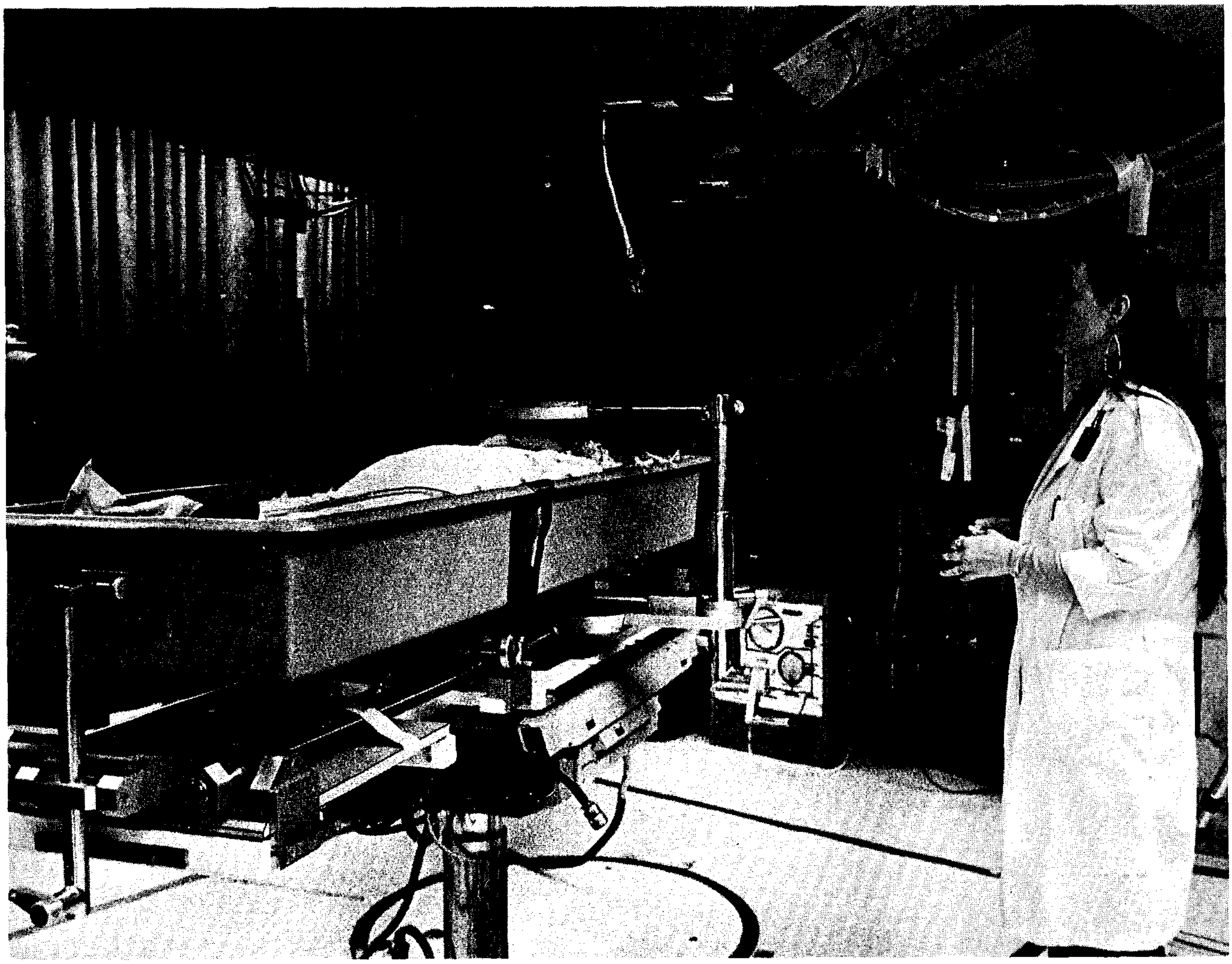
At the LAMPF biomedical facility, a team that involves physicians, physicists and technicians has treated 67 cancer patients of various ages in the past four years. The first patient received pion treatments in October of 1974, and three other persons were treated by Christmas of that year. Due to mechanical refurbishing and installation of shielding, no patients could be treated for the next 18 months; the treatments began again in June, 1976.

Currently, 13 patients are involved in this unique program. They come from as far away as





'Pion therapy is just in its infancy' - Morton Kligerman, M.D.



Radiation technologist Carolyn Blies, in this and succeeding photos, readies a patient for pion treatment at the biomedical facility. Although some tumor regression has been noted, the staff is not ready to call the cancer research a breakthrough.

Boston, Los Angeles, and the Chicago area, although half are from New Mexico. Researchers must turn away many persons from throughout the world who inquire about the promise of pions, because their tumors are not amenable to pion treatment — or because there is not enough beam time.

Treatments are scheduled when the LAMPF beam is running, so the biomedical facility and its staff are busy during these periods; they may work over a 16-hour treatment day, sometimes finishing a cycle at 6 a.m.

Patients spend 10 to 40 minutes under the pion beam, usually twice or more times per day, five days a week. Individualized treatment involves body molds that hold a patient steady during the sessions, and the pion beam is shaped to direct the proper dose to the appropriate area in each person.

"Our goal is not to take cases where we already do well with other types of treatments," said Kligerman. "We're looking at patients who cannot be treated adequately with conventional methods or combinations that include surgery, radiation, and drugs."

Kligerman also said he would be discussing results at The Hague,

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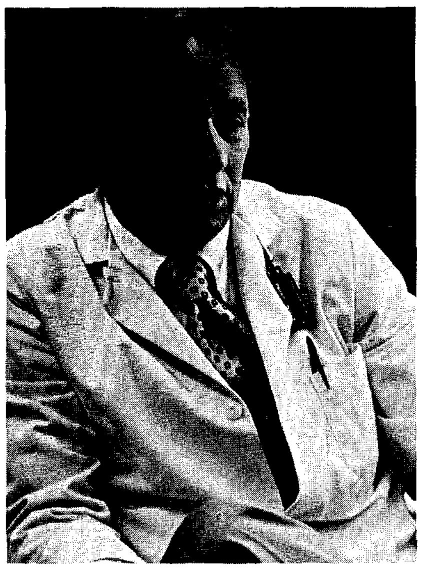


'We are looking for local control where cancer has started.' — Malcolm Bagshaw, M.D.

'It will take years to say whether pion therapy is superior to other treatments'

The Netherlands, this fall during a third annual international meeting that covers particle therapy programs from all over the world. He noted that pion therapy has been of benefit to 80 per cent of the patients, improving their ability to lead near-normal lives and prolonging their span of comfort. But he added that insufficient time has elapsed to assess the impact on long-term survival.

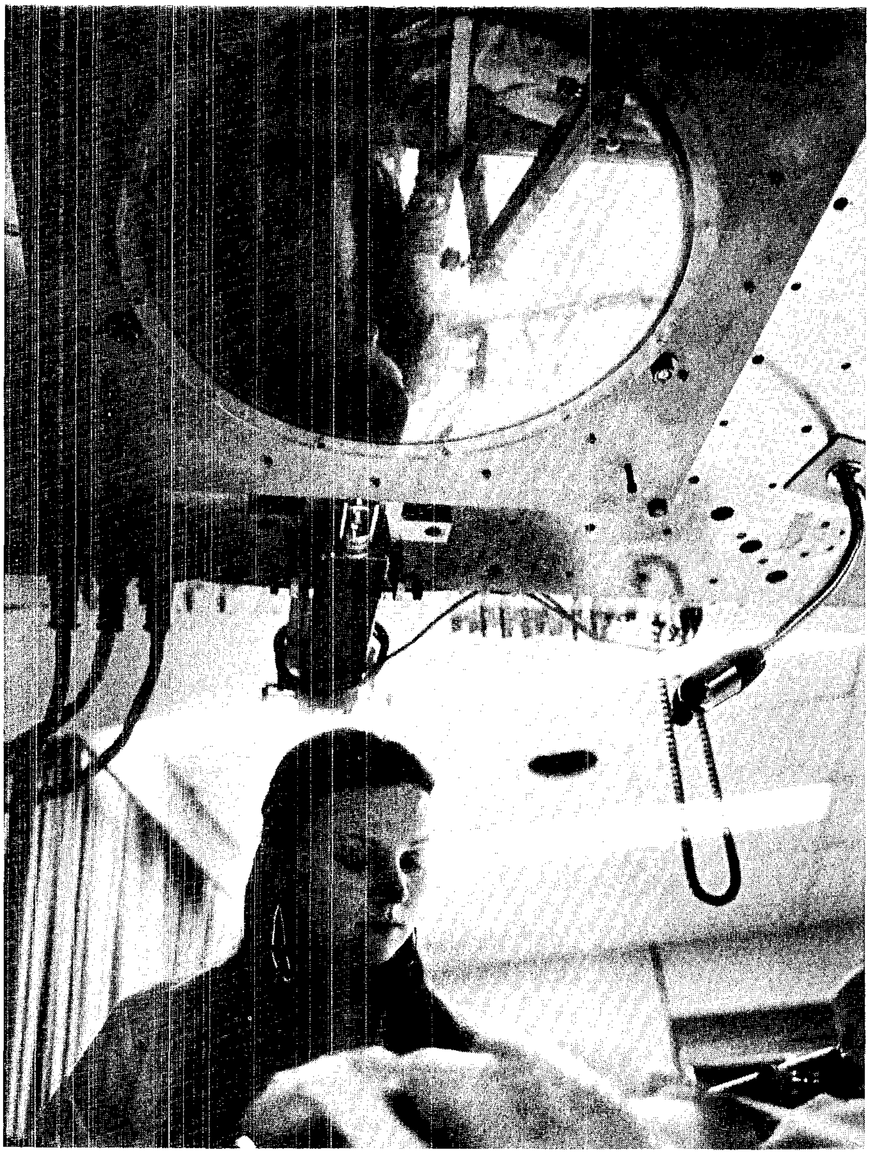
Dramatic results needed

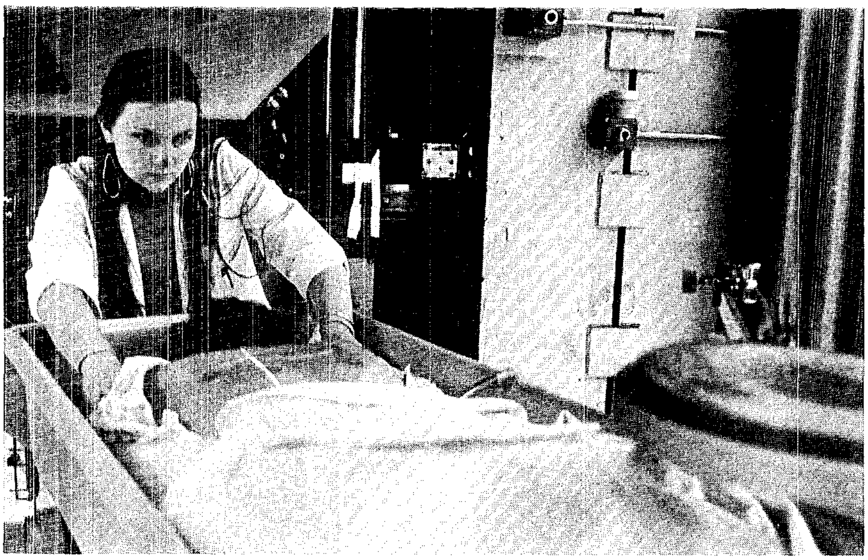
Pion therapy will need dramatic clinical results to be impressive, said Kligerman: "If the cure rate for cancer of the lung is seven per cent, and we increase that by 10 per cent, we still only have a cure rate of 7.7 per cent. But if we can increase the rate by 100 to 200 per cent, we can show results."

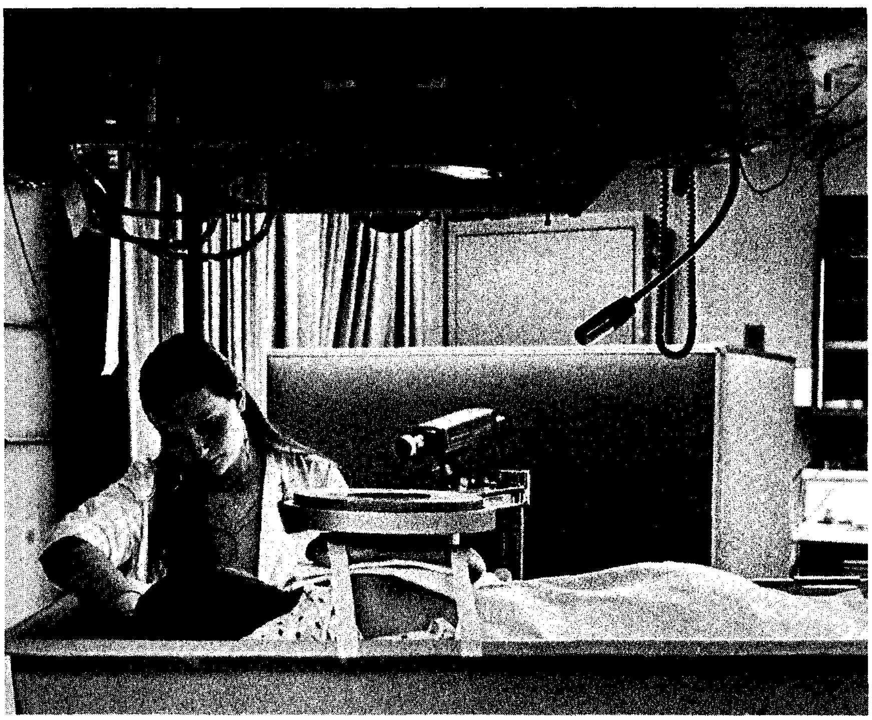
Malignancies treated with the LAMPF beam include solid tumors of the brain, head and neck, abdomen, and pelvis. Patients with some of these afflictions may be cured with conventional treatment if their cancers have been detected at an early stage, but those accepted into the program are all in the advanced stages of the disease.

"Local control" is important, said Kligerman, because a large percentage of the cancer patients who die have succumbed from continued growth of the primary tumor. In addition, the more cancer cells that can be destroyed with pions, the lesser chance there is for cancer spreading in the body — and the more effective drugs can be in destroying small deposits of the spread.

Chemotherapy and immunotherapy "are weak in their ability to



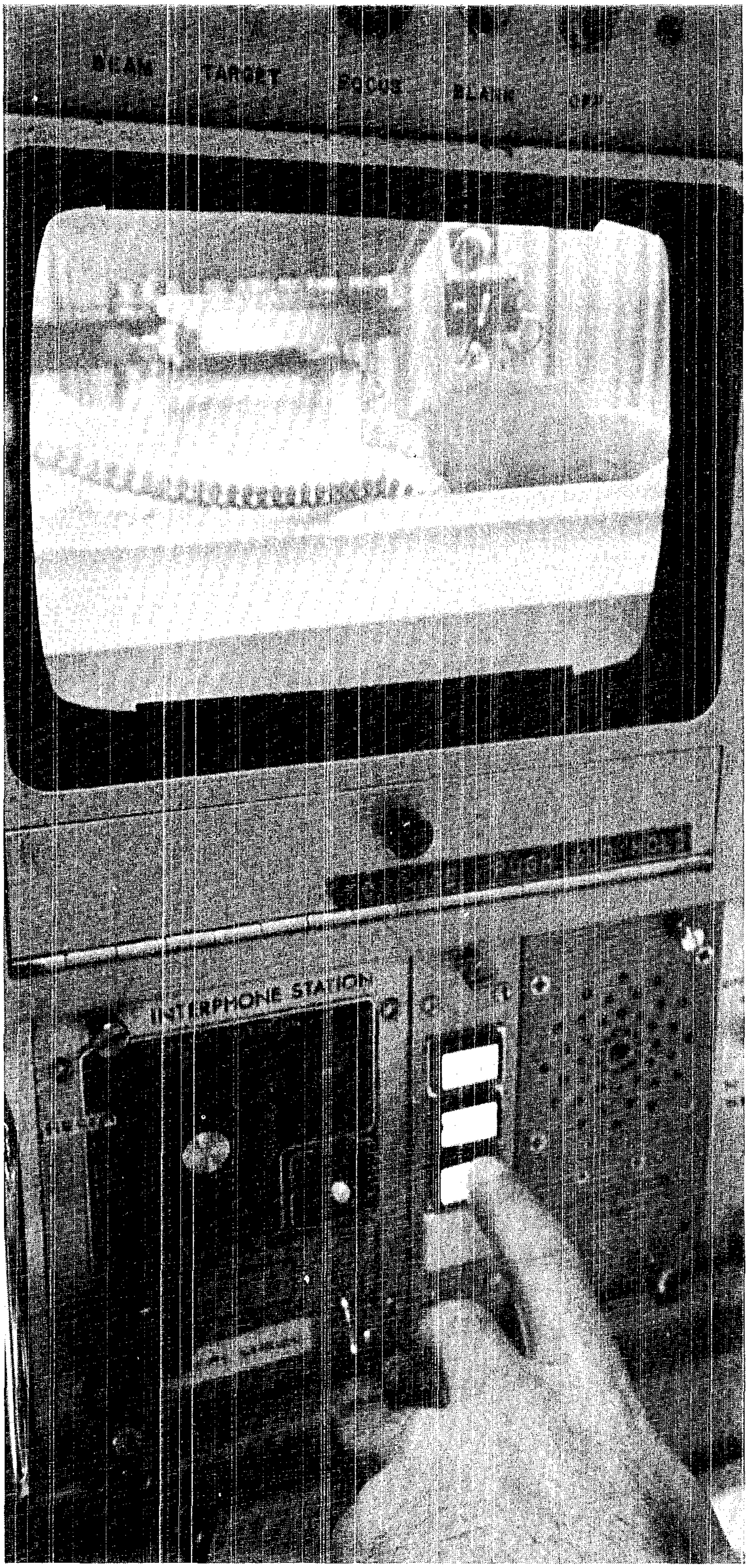




locally control a mass," said Kligerman. But these alternate types of treatment have higher chances of success when combined with radiotherapy, surgery, or both, he added.

Many patients have exhibited relatively marked tumor regression, with little or no reaction in the normal surrounding tissues. This indicates that pions may have a greater effect on some tumors than on the normal tissues where they arise, but data are not yet sufficient to draw firm conclusions.

Researchers have seen minimal side effects with pion therapy at dose levels so far given. The pion doses are gradually being raised at each treatment cycle until the maximum tolerance of normal tissues — such as oral mucosa, intestines, and lungs — can be determined.



Malignancies treated include solid tumors of the brain, head and neck, abdomen, and pelvis

Personnel other than patients are not allowed in the treatment area when the pion beam is being directed at tumors. A series of cameras allows the staff to watch the patient on a monitor screen; patient and staff can talk back and forth with microphones during treatment.

Kligerman said that studies at LAMPF are in an intermediate phase, that results are subject to change, and that rates of side effects could go up. But the fact remains that the tumors which regressed in the program here have done so faster than in other types of therapy, he added.

Other treatment programs are underway around the world, Bagshaw pointed out, and pion therapy is just one aspect of particle therapy in general. In addition to the many active neutron facilities, types of heavy ions from carbon and nitrogen will be investigated at Berkeley. European cooperation is evident in a pion project at the Swiss Institute of Nuclear Physics, which includes a physician who just completed a one-year stay in Los Alamos.

At Stanford, particles flying off a bombarded target are picked up by a large superconducting magnet and could be directed to a treatment area. The Canadian TRIUMF facility in Vancouver, British Columbia, is preparing for the clinical phase of pion experimentation, and the Japanese are showing interest in the program as well, Bagshaw said.

Physics and biology problems can also be explored through the pion program, Kligerman said, but the direction is always toward helping to improve the safety and effectiveness of cancer care, he added.

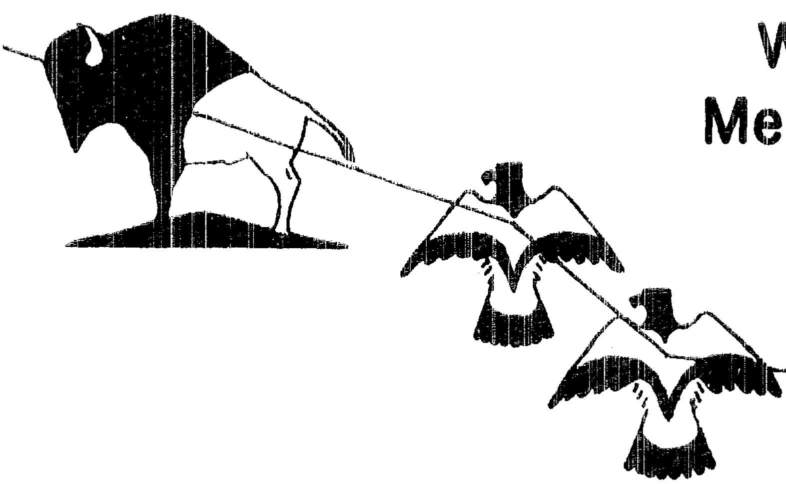
Particle programs are underway throughout the world

Guarded optimism

To date, there is guarded optimism in the pion program, but the future is not certain.

"Whether we go on depends on our results," Kligerman said. "But if we do go on, it will hopefully be cheaper with the PIGMI program now under investigation, and we're thinking about this aspect also."

From the master computer control room, all parts of the biomedical facility are monitored and measurements constantly read. Manning the center are Gene Purkiss and Roy Slice.



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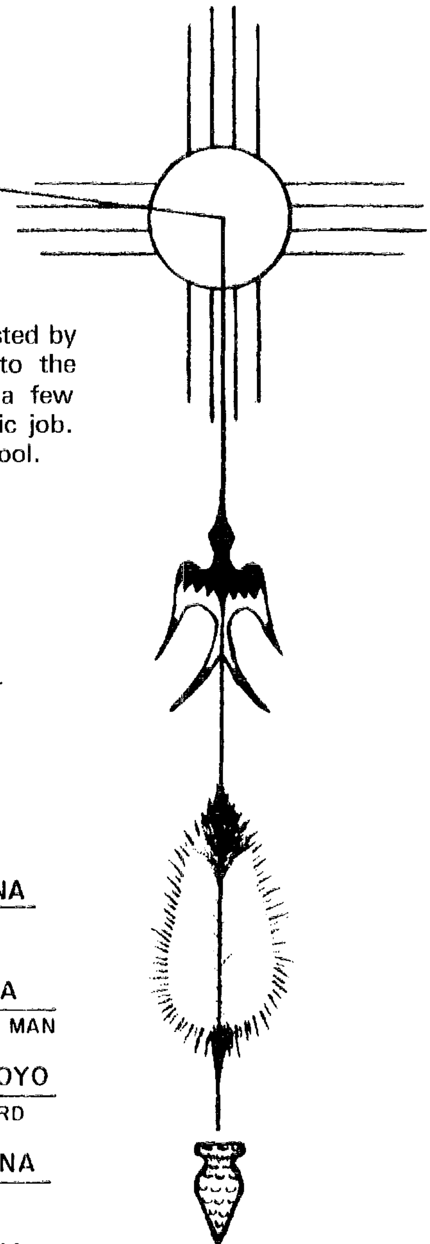
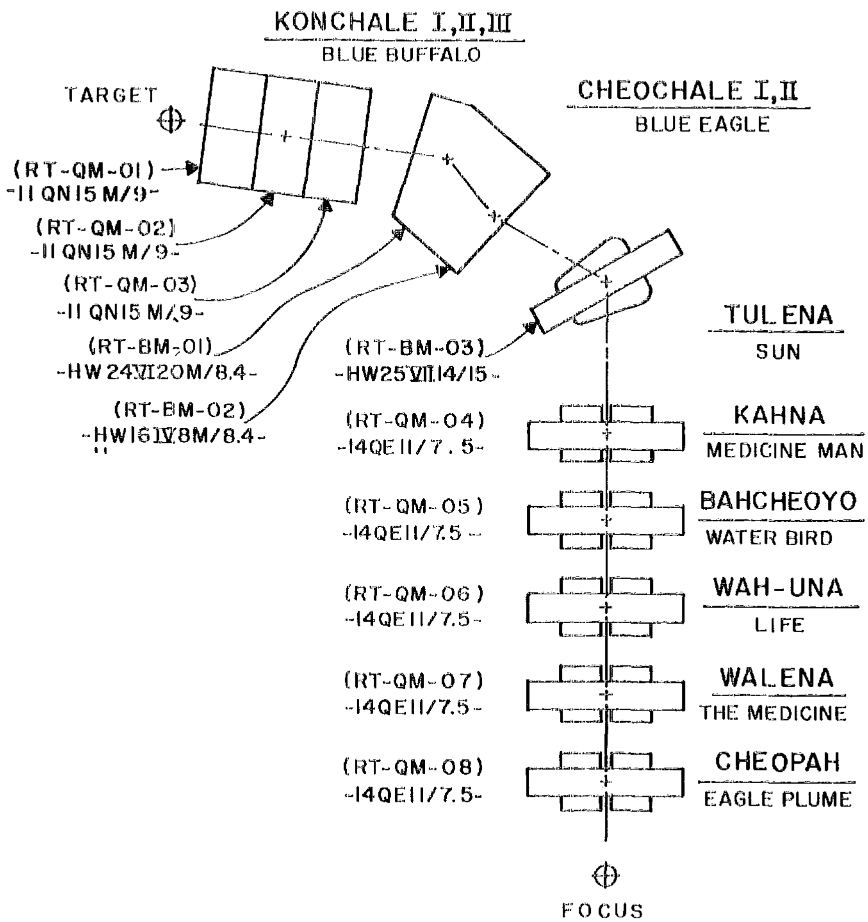


Gilbert Suazo, a LAMPF senior fabrication technician in MP-8, assisted by his wife Martha, both residents of Taos Pueblo, gave names to the numerous magnets of the biomedical beam line. Some weigh a few ounces, others thousands of pounds, and each performs a specific job. The names, from Tiwa dialect, have become part of this research tool.

BIOMEDICAL BEAM LINE MAGNET SCHEMATIC



Meet PIGMI: small brother to the meson facility

An ion source prototype, displayed by Bob Hamm, is encapsulated by an insulating blanket of gas. If a problem develops in the central working portion where an arc is struck to create ions, the electric load is 'dumped' across the metallic spheres.

"The whole idea is to make a small accelerator for hospitals that will treat cancer patients," said Don Swenson. "We hope it will be much smaller, and certainly less expensive, than its big brother."

A simple concept. But how does one design and build a proton accelerator that is just 120 meters long, in contrast to its "big brother," the 850-meter-long LAMPF — Clinton P. Anderson Los Alamos Meson Physics Facility? And how does one build a new breed of machine that will be powerful, yet reasonably priced with regional hospitals in mind?

"We had to make some fundamental developments," answered Swenson, leader of the Linac Technology Group (AT-1) of the Accelerator Technology Division. "Our goal is to make PIGMI the length of a football field. Increasing the rate of acceleration will reduce the length of the facility, and using a higher radio frequency than that of LAMPF will also help cut expenses."

'Our goal is to make PIGMI the length of a football field'

The background

PIGMI, for the uninitiated, stands for "Pion Generator for Medical Irradiations." The project began about two years ago in the Medium Energy Physics Division, which operates LAMPF, and involves people from there and from AT-Division. Progress has been made; prototypes of key PIGMI parts will be completed by the end of the year.

"We think PIGMI can be built for about $10 million, and a small neutron-producing version could be constructed for less than $2 million. Whether this will sell like hotcakes or not, we don't yet completely know," said Swenson.

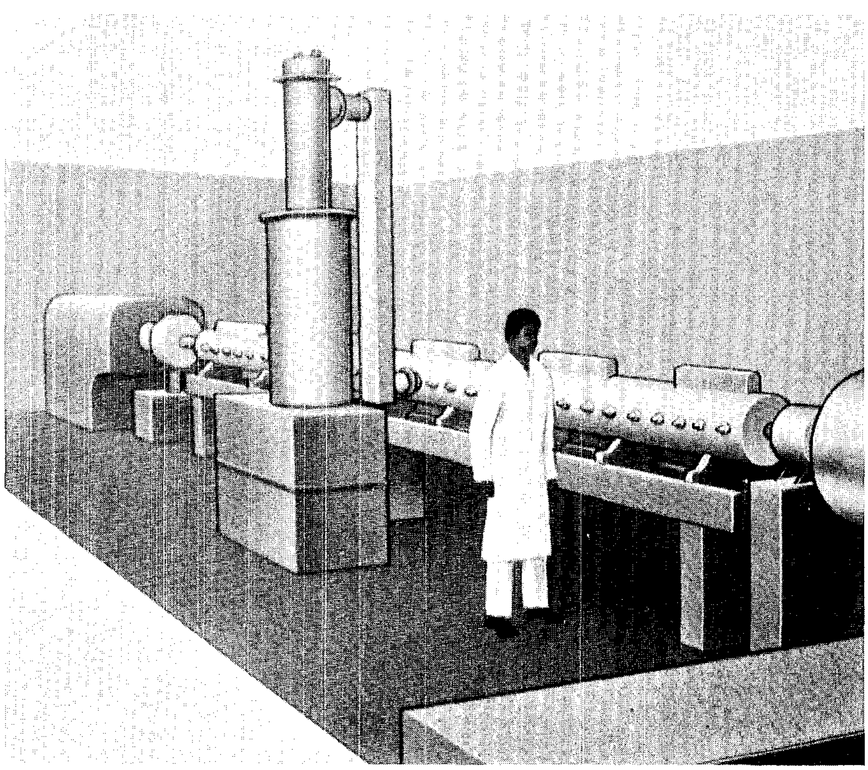
At the large LAMPF complex, patients have been treated for tumors under the direction of Morton Kligerman, assistant director for radiation therapy at LASL, and also director of the University of New Mexico Cancer Research and Treatment Center. Part of the powerful LAMPF beam line is diverted by large magnets to the biomedical facilities, after protons strike a target to produce pions.

The uniqueness of pions (pi mesons) is their ability to be easily captured by a nucleus, and then explode it by converting mass into energy. In this way, ionizing radiation is released under tightly controlled conditions and destroys cancer cells at prescribed depths in the human body — minimizing damage to surrounding healthy tissue.

But there are only a few places in the world where pion therapy can be applied to patients suffering from cancer. Mention is made of Berkeley, Russia, Canada, and Switzerland, but only LAMPF at present has enough pion production to be effective.

PIGMI will have to perform a task that only its big brother so far has accomplished: the acceleration of intense quantities of protons to 75 per cent of the speed of light. While LAMPF can reach energies of 800 million electron volts, with an intensity approaching one milliampere, PIGMI must reach energies of 650 million electron volts with an intensity of 0.1 milliampere. And PIGMI will have to do this in one-sixth of the distance available to LAMPF.

The "front end," or injector area of PIGMI, will be room-sized, compared with the four-story Cockroft Walton injectors of LAMPF. This smaller size, in terms of height and length, would enable a hospital to consider building the machine underground — perhaps below a parking lot. Innovations in the program, which is supported by HEW's National Cancer Institute,



The 'front end' of PIGMI could look like this after assembly; a crew of perhaps a dozen persons could operate it at a regional hospital.

would also allow a hospital to operate a PIGMI machine with a smaller staff than is required at a large accelerator. A staff of a dozen would most likely suffice.

In addition, hospitals could use proton linear accelerators to produce neutrons for radiotherapy, radioisotopes for the growing field of nuclear medicine, and for charged particle radiography. Related programs are underway now at Los Alamos.

"Pions are an expensive but unique particle," noted Swenson, who has designed important elements of PIGMI. "They are the only ones of the atomic 'menu' that slow down and stop at controllable points in matter, and then cause a nuclear explosion — one atom's worth. The charged fragments damage cells and tissue in the tumor."

The goal at LASL is now to build a prototype of the first and most difficult part of the PIGMI machine and test it by the end of 1978. If the first three meters of PIGMI (where work by Lash Hansborough of AT-1 and Val Hart of MP-8 has been important) is successful, the Laboratory can take one of two routes.

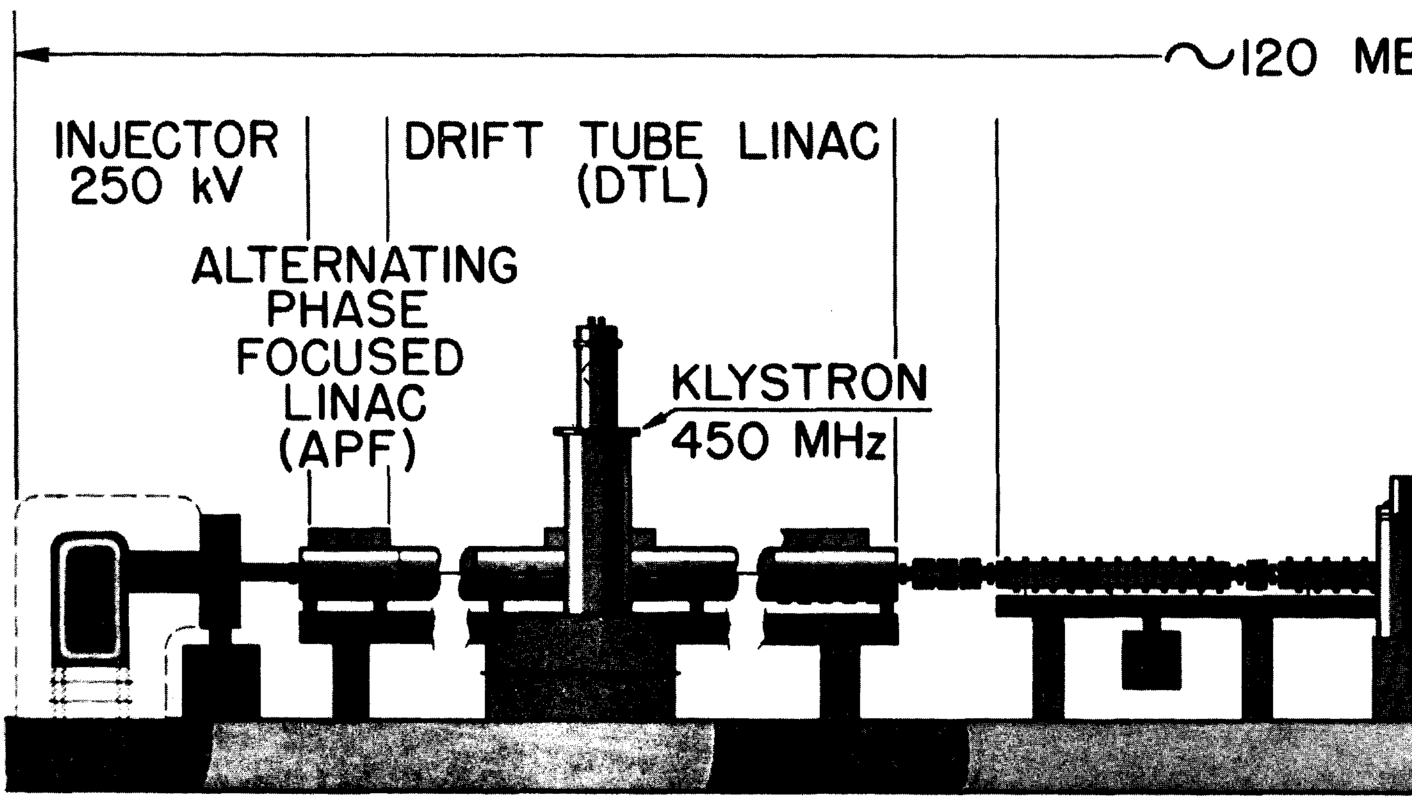
LASL could seek support with a major medical center to extend the design and then participate in the fabrication of a full-scale PIGMI. Or a smaller version that uses the same technology, but which would produce abundant quantities of neutrons, instead of pions, could be pursued. In either case, the machine could be assembled and completely operated in Los Alamos to ensure its reliability, then moved to a medical facility. Many people, including researchers from Denver hospitals, Stanford University, and Pennsylvania institutions, are awaiting the outcome.

Designing PIGMI

"It has been our primary thesis since the very beginning that the cost and complexity of this linear accelerator could be reduced in a number of ways," said Swenson. "This includes raising the frequency, reducing the diameter of the cavity, raising the acceleration gradient, reducing its length, and lowering the required energy of the injector, which also reduces the injector's size and complexity. But to take advantage of these trends, it was necessary to develop suitable focusing schemes to contain the beam within the smaller structure."

The problem is most severe within the first few meters of PIGMI, where the space available for focusing is completely inade-

About football-field-length, the PIGMI machine would be powerful and compact; but the seemingly simple concept required several fundamental developments in physics design and engineering.



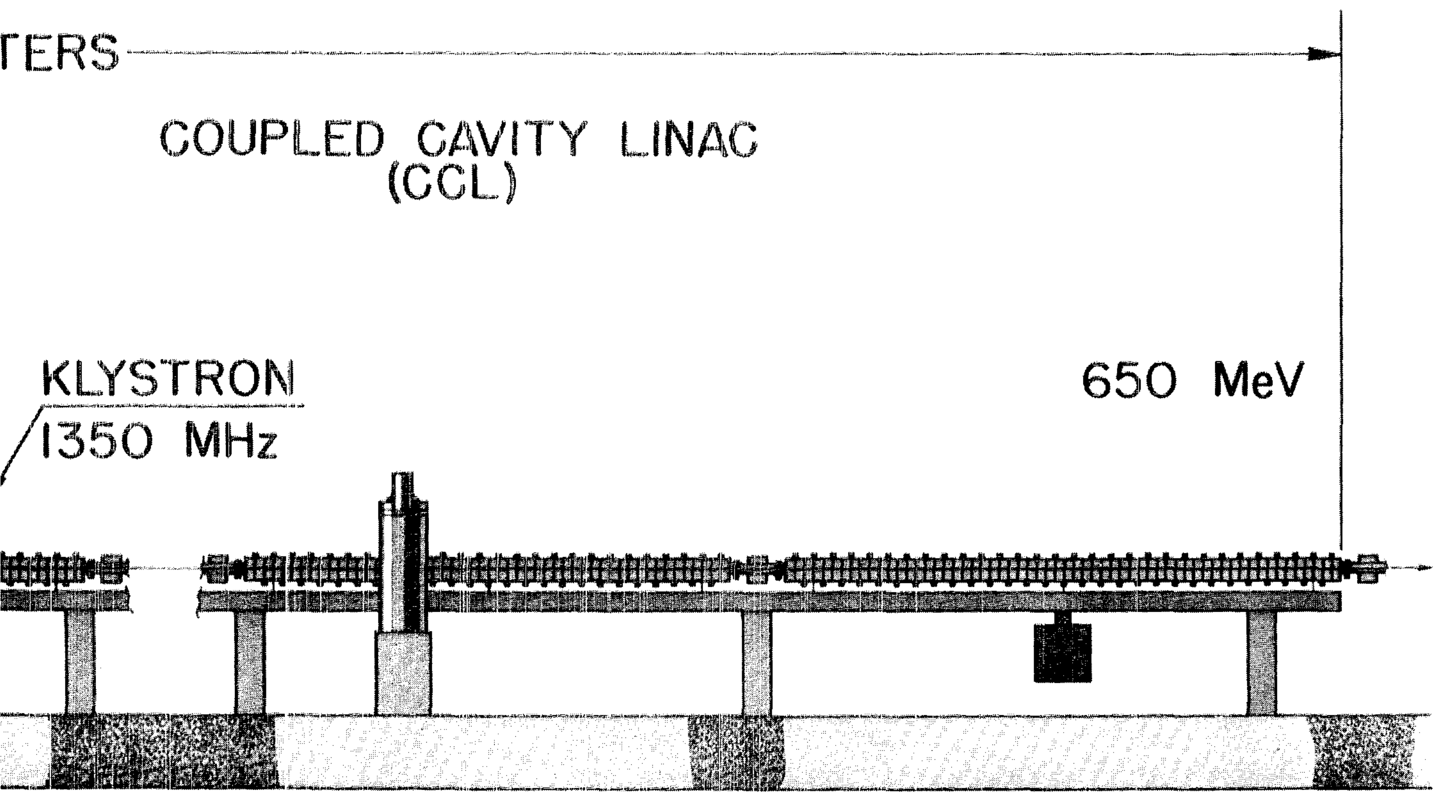
quate if conventional techniques were to be used. It is here that Swenson's group investigated and developed an alternating phase-focused scheme where the electromagnetic rf fields themselves, in addition to accelerating the beam, alternately focus and then defocus the beam — in both the longitudinal and transverse directions.

Past the first few meters of the structure, AT-Division proposes to solve the focusing problem with permanent magnet quadrupole lenses that can be considerably smaller than their electromagnetic cousins at LAMPF.

"For the high-energy portion of the machine," said AT-Division leader Ed Knapp, "we planned originally to use the side-coupled structure, developed here for the large meson facility. But in the course of looking for ways to make improvements, we found one in the work of our Soviet colleagues at the Radio Technical Institute of Moscow. They plan to use a 'disk and washer' structure in the Russian version of LAMPF now under construction. Joe Manca, Jim Potter, and Fred Humphry, all AT-1, have studied this structure for two years now, with very powerful computational tools and laboratory models, and have made a number of improvements to it."

Some researchers have favored the use of electron accelerators to produce pions for cancer research. But although electrons are relatively easy to accelerate in modern-day physics, they are needed in numbers 30 to 50 times greater than the heavier protons to produce the same intensity of pions. In a machine like PIGMI, protons constantly change velocity, so the

Pions explode a cell nucleus by converting mass into energy

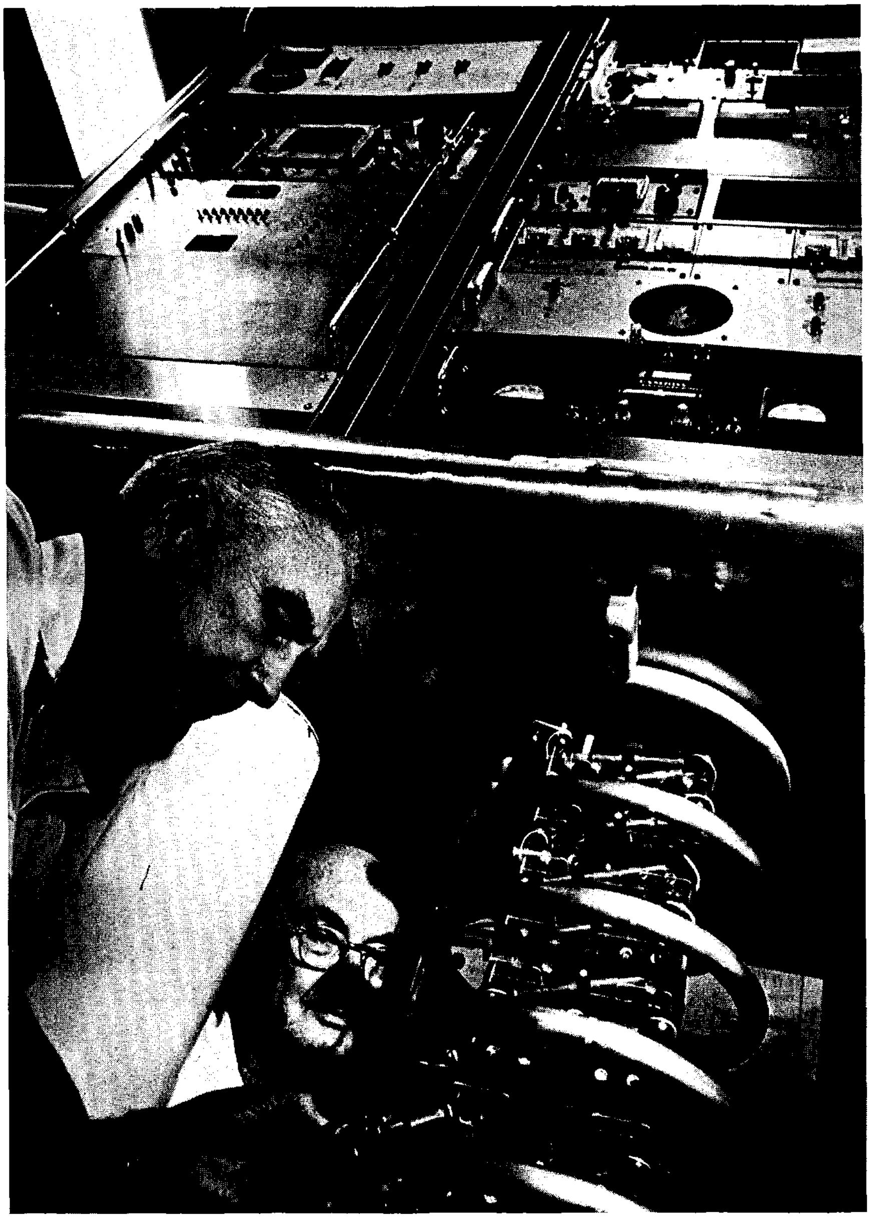


accelerator itself must change in design along the way. At LASL, the team has chosen the proton accelerator approach for PIGMI and has set goals of simplifying the design and reducing the cost of LAMPF's little brother.

How will it work?

Each part of PIGMI is used only once to interact with a given bunch of particles as they move down the beam line in a few millionths of a second. Compared with circular "meson factories," PIGMI would be powerful. The electromagnetic rf fields, set up by the klystron devices (see accompanying sketch), reverse directions at the rate of 450 million times each second. Shields at specific locations prevent the deceleration of particles, which are only affected by the accelerating forces. So the particles' velocities increase by a series of "kicks."

The proton beam starts at the injector room, the design of which has involved work by Bob Hamm, Harold Lederer, and Don Mueller of MP-12. A 250-kilovolt power supply and a duo-plasmatron ion source with an accelerating column produce a beam of protons that is only a few millimeters in diameter. The ion source strikes an electric arc in the plasma of hydrogen gas, stripping off electrons. The gas goes to an expansion cup, from which protons can be extracted.



Harold Lederer and Bob Sturgess test the operation of part of the PIGMI injector system, a 250-kilovolt power supply that is room-sized, in contrast to the four-story injectors at the meson facility where patients are now being tested.

The beam is now bunched with the aid of a double harmonic buncher, a piece of hardware never before built, that can be excited at 450 and 900 megaHertz simultaneously in a single cavity. The beam is also focused by a solenoid magnet of an advanced design, executed by Ed Bush of MP-8 and by the Lawrence Berkeley Laboratory.

In this same region, beam properties will be measured and tuned to ensure the proper conditions for injection into the linear accelerator portion of the machine. The measurements and computer-based diagnostic system are the responsibility of Jim Stovall, Shirley Klosterbuer, and Vince Martinez, all AT-1.

The protons have not yet traveled far when they reach one of the key elements of PIGMI, the alternating phase-focused linac. Most linear accelerators today use quadrupole lenses, effectively making four components from the beam. The PIGMI needed a new structure for the low-voltage injector and the high-frequency, high-gradient acceleration. By arranging the drift tube lengths and the gap positions, particles are exposed to electric fields at different intervals (alternately short, medium, and long gaps). This causes the particles to be focused and defocused, affecting the beam diameter.

This means the drift tube, through which the beam passes, can be made smaller than ever before. It also means PIGMI can have higher frequencies of beam, while at the same time using lower energies. "It has been the want of the alternating phase-focused linac

Will accelerate protons to 75 per cent of the speed of light

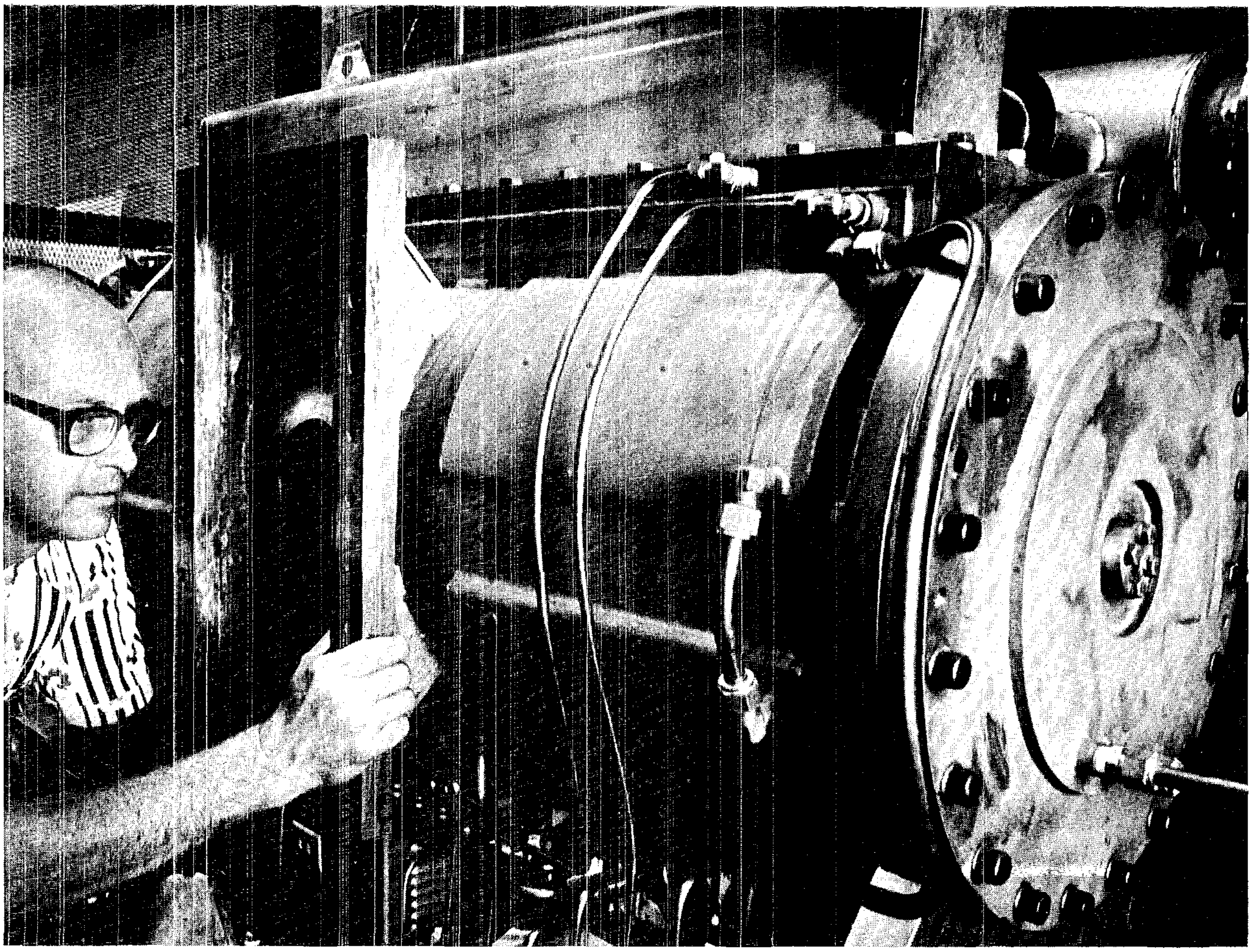
that has kept other developments at bay," Swenson added.

Permanent magnetic quadrupoles are another PIGMI innovation, due in great part to Japanese visitor Norio Saito, who has now returned to his homeland. Normally, accelerators utilize quality iron cores with electric wire windings to hold a stable electric field. But the smaller, rare-earth cobalt magnets are effective permanently without any wire windings. They require no power supply, no cooling, no control, and there is no electric "ripple."

"There are outstanding talents in the group for developing rf sources," Swenson continued," "but we have chosen the PIGMI frequencies to be compatible with commercially available klystrons developed for defense applications." PIGMI contains two types of klystrons, one for the drift tube linear accelerator and one for the "power end," the coupled-cavity linear accelerator.

Here the "disk and washer" structure developed in Russia is employed. Swenson explained that the cell-to-cell coupling coefficient is rated at 50 per cent, compared to the five per cent value at LAMPF. And here, PIGMI's beam will reach its intensity of 650 million electron volts, at a tenth of the current used at LAMPF. This translates into a less expensive machine.

Another possible feature for PIGMI was developed during the past year by Hikaru Inoue, another Japanese visitor who also has returned home after a one-year Los Alamos stay. A system of magnets could be used to allow the facility to be "bent back" on itself in the center, thereby reducing the length and required real estate.



Val Hart works on 'piglet,' a test cavity used for engineering and fabrication studies. The device is also used to glean data from field gradient tests as the PIGMI prototypes near completion.

This system of magnets would need very special properties: it would be able to bend all components of the beam by the same amount, and do so in the same amount of time regardless of the range of particle energies within the beam. This combination of achromatic and isochronous conditions has never been designed before, to Swenson's knowledge.

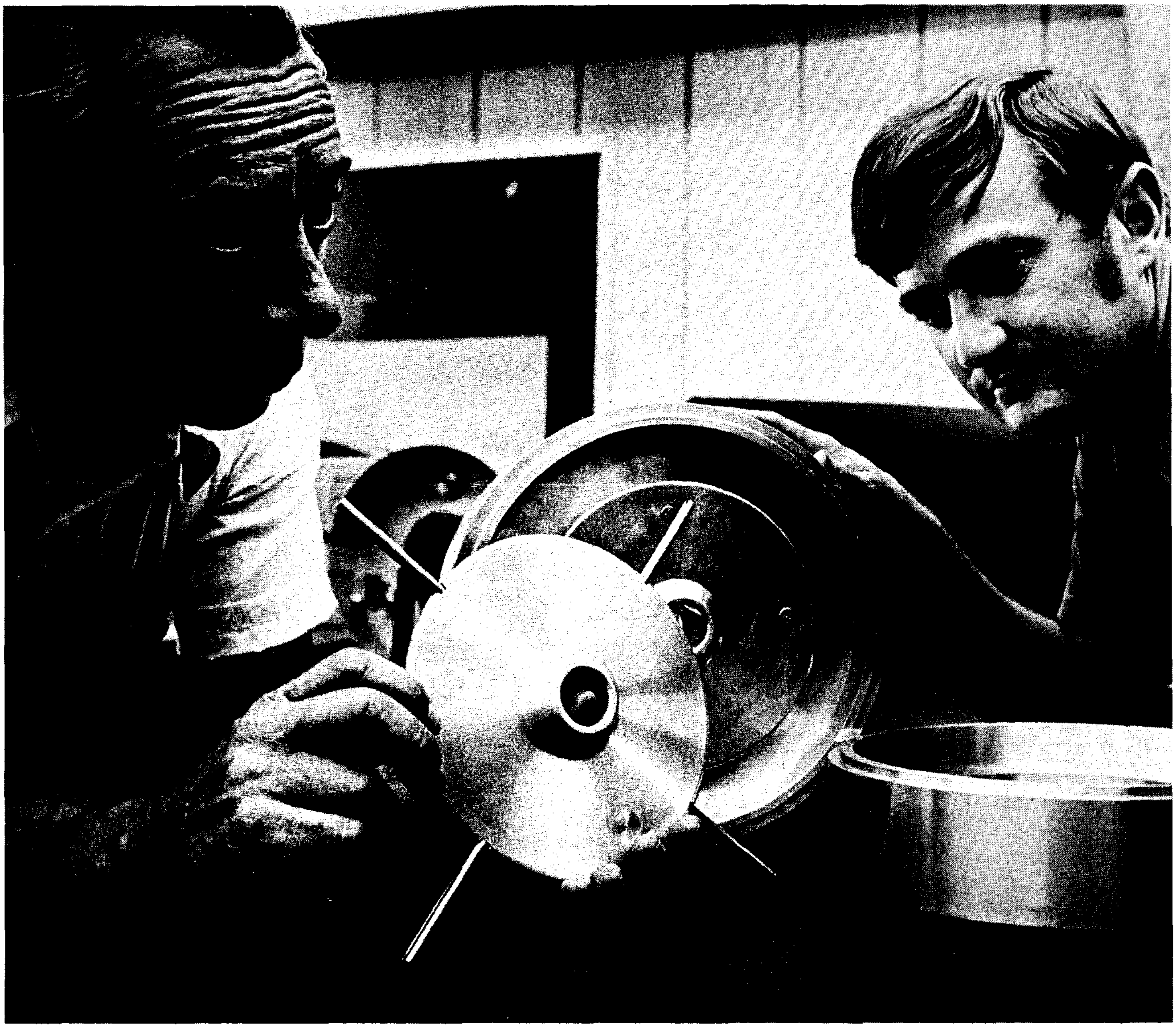
The beam is directed to the treatment area, where several targets may be available. Many pion channels, using magnets and apertures, select a certain set of pions and direct them to cancer patients.

From the lab, into the world

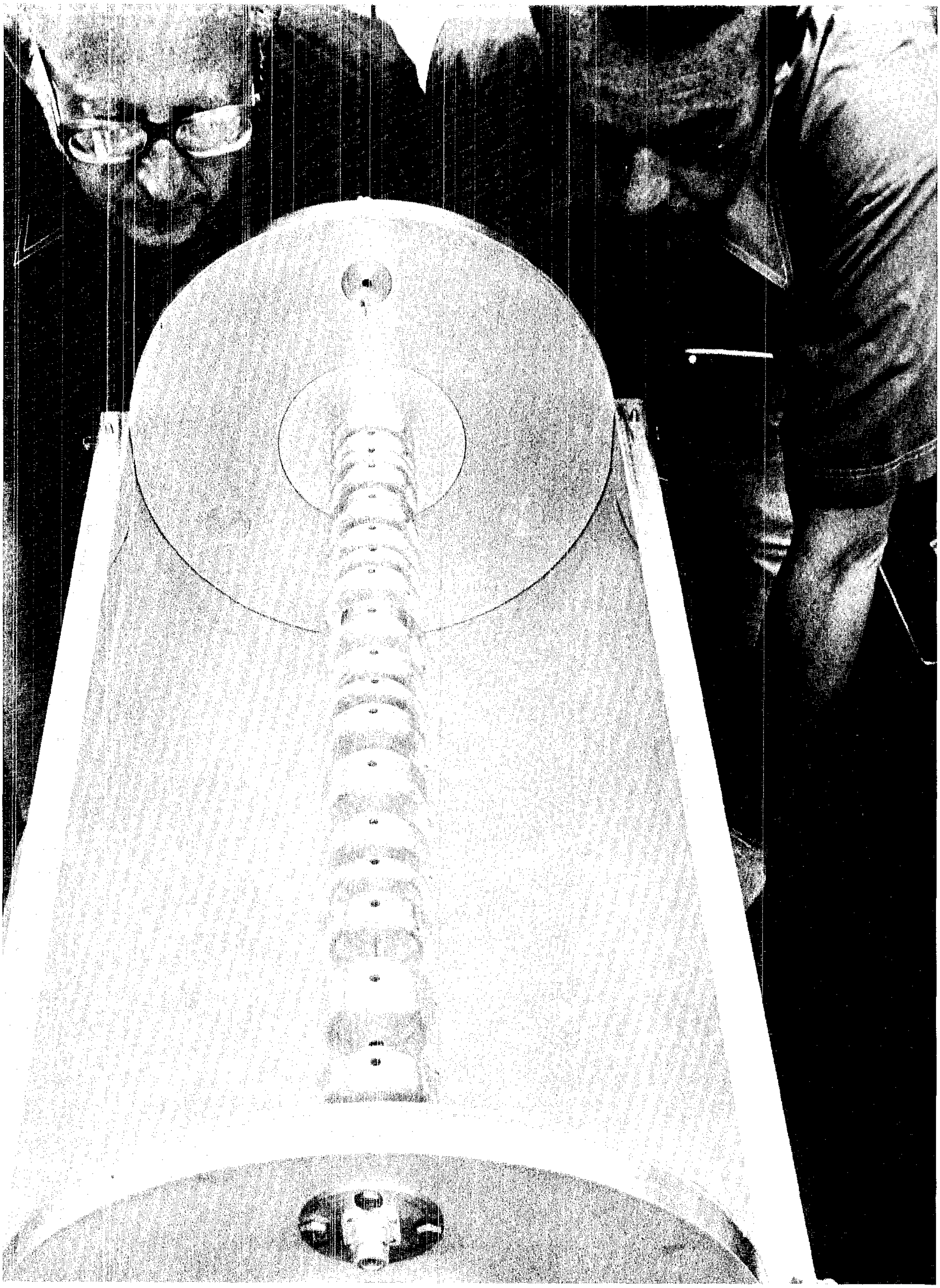
The targets would be "hot" in the radioactive sense, as they are at LAMPF, but other parts of PIGMI should not pose problems for maintenance personnel.

In the future, a hospital could have several treatment areas for patients, who would spend 15 minutes or less each time they were treated with pions. Assuming a PIGMI use of 10 hours a day, with three or four treatment areas, 100 treatments a day or more would be feasible. Many medical institutions in the country currently have that much demand for a PIGMI machine.

"This represents a new breed of linear accelerator," said Swenson. "One of our interests is to bring it out of the physics labs and out into the world."



The 'disk and washer' system, adapted from a Russian design and examined by Fred Humphry and Dave Keffler, has a high coupling coefficient and will aid in reducing PIGMI's cost. The radially-stemmed piece is a newer experimental design.



Developed at LASL, the alternating phase-focused linac assembly, shown by Don Swenson and Ed Bush, is expected to focus the PIGMI beam in a small amount of space.

10 Years Ago

TRANSFER OF ROSER

Herman E. Roser, Manager of the AEC's Los Alamos Area Office since February, 1967, will transfer to Commission headquarters in Washington, D.C. soon as assistant director of the Division of Military Application. In his new position, Roser will assist the director of DMA in the development of programs and plans and in the management of commission's research development, testing and production activities for nuclear weapons. Roser joined the AEC in 1961.

SUPERMARKET SPECIALS

Items on sale at a local store included the following: coffee - 56¢ lb.; 200-count facial tissue - 18¢; hen turkeys - 38¢ lb.; fancy apples - 22¢ lb.

HONOR FOR MARIA

Maria Martinez, "The Potter of San Ildefonso," will receive a special citation from the president and board of trustees of the American Ceramic Society at the group's 21st Pacific Coast Regional Meeting to be held this month.

This will be only the third time in the 69-year history of the Society that such an award has been made. Living in the pueblo of San Ildefonso near Los Alamos, Maria's unusual qualities have gained her fame throughout the world. The American Ceramic Society is an organization of more than 10,000 ceramic engineers, scientists, educators, suppliers, and industrial designers from the United States and 52 other countries.

EXHIBIT AT BERKELEY

LASL's exhibit at the University of California's Centennial Caravan attracted the attention of many campus officials at the opening of the traveling show at the Harmon Gymnasium in Berkeley last week. A model of MP-Division's Electron Prototype Accelerator and a large color panorama of Los Alamos are featured in the display. The caravan which portrays 100 years of University history and achievements will travel to various locations in the state.

Culled from the October, 1968
files of *The Atom*
and the *Los Alamos Monitor*
by Robert Y. Porton

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Working the United Way

As you read this issue of the Atom, the United Way fund drive for 1979 will be underway — but far from finished. Your help is needed if the goal of $245,000 is to be reached in October.

Each LASL employee will receive a brochure explaining United Way activities and an envelope, to be used when forwarding donations to one of the Laboratory campaign volunteers. Gifts are totally voluntary, and any amount given is held strictly in confidence.

The United Way drive, conducted once a year, is a chance to support 20 human care agencies at one time. Many of the agencies assist residents of more than one county, if neighboring counties have no United Way program. In Rio Arriba County, for instance, United Way funds help support Jemez House, the Salvation Army, the Heart Association and the Cancer Clinic.

According to Alice Brock, United Way President, last year's goal of $230,000 was exceeded; the final figure of $245,000 that was reached then is this year's objective. Donations may be given to LASL employees who will wear special buttons, or they may be sent, when not made on an installment plan, to: Los Alamos Area United Way, Inc., P.O. Box 539, Los Alamos NM 87544; or call 662-3264.

Projects among the 20 United Way members include establishment of a group home in Los Alamos for retarded adults. This is undertaken by the Association for Retarded Citizens, which provides recreation for children and adults, counsels parents, and provides scholarships for work with the retarded.

Self Help, Inc., has hired a part-time paralegal aide to help provide organizations and individuals with free legal assistance, when that help would otherwise not be forthcoming. Self Help also employs an attorney.

The Visiting Nurse Service helps persons whose ages range from 15 months to 91 years. It brings skilled care, psychiatric nursing, therapy, and social services to the disabled in their homes — regardless of ability to pay.

The campaign chairman this year for United Way is Virginia Kyle. Team leaders are: Shirley Sundberg of LASL; Carol Paxton of Zia/LACI; Bob Ziemer of the county; Gene Ebinger from the school district; Maxine Whitmore of the medical center; Josephine Martinez from the federal branch; Mary Ann Jakowski of EG&G; Winifred Amsden of the retired community; and the Chamber of Commerce board.

The board of trustees is: president Alice Brock, vice president Lawry Mann, secretary Norma Liebenberg, treasurer Elizabeth Dahl, financial secretary Charles Cozzens, and members Louis Fuka, Frank Guevara, Robert Hamblet, William McCreary, Clyde Reed, and Shirley Sundberg.

1979 Goals:

USO - $400; Council on Alcoholism - $13,950; American Red Cross, $9,200; Association for Retarded Citizens - $12,000; Chaparral Home and Adoption Services - $2,100; Salvation Army - $9,000; Cystic Fibrosis Foundation - $1,000; Los Alamos Workshop - $26,000; Jemez House - $30,740; Cancer Clinic - $1,000; Casa Mesita - $5,000; Girl Scouts of the U.S.A. - $16,456; Family Council - $37,500; Self Help, Inc. - $10,600; Visiting Nurse Service - $16,000; Heart Association - $8,000; Arthritis Foundation - $4,000; Boy Scouts of America - $13,462; Family YMCA - $17,840; New Mexico Council on Crime and Delinquency - $2,000.

The smallest drift tube configuration explored for the PIGMI accelerator prototype is examined by Lash Hansborough and Jerry Johnson, both AT-1. Testing of critical parts for PIGMI — destined for availability at regional hospitals — should be completed this fall.